RESEARCH DEPARTMENT

Information on Short-Wave Propagation Conditions from Reception Results on Fixed Frequencies

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THE BRITISH BROADCASTING CORPORATION
ENGINEERING DIVISION

RESEARCH DEPARTMENT

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1. SUMMARY.

Regular hourly observations made at Panorama, South Africa, on reception of five fixed frequencies from Standard Frequency Station WWV have been analysed to obtain information on propagation conditions and their daily and seasonal variations, for comparison with those given by world charts of predicted MUF. The results indicate that the predictions agree well with actual conditions over this transmission path during the early morning and forenoon periods, and to a certain extent after noon GMT. The decrease in predicted daytime MUF from February towards June is, however, much greater than that obtained in practice. The peak value of frequency upon which good reception is obtained is, in fact, shown to decrease by only about 9% during these months, whereas the predicted MUF decreases by about 28%.

The analysis shows that during certain months propagation conditions deteriorate after sunset at Panorama, so that, after the time when this effect begins, the frequencies on which good reception can be obtained (when such exist) lie considerably below the predicted MUF.

2. INTRODUCTION.

One way of observing the variations in propagation conditions over a short-wave transmission path is to make regular hourly checks of the reception conditions upon the signals from a given transmitting station upon a number of fixed frequencies. Normally, however, transmitting stations do not continue to work simultaneously upon a number of fixed frequencies, but choose their frequencies to suit the changing propagation conditions over a given path from time to time. Transmitting stations engaged in transmitting Standard Frequency Signals do, however, radiate their signals continuously upon fixed frequencies, and one such station is that of the National Bureau of Standards at Washington, D.C., U.S.A., with the call-sign WWV.

About the middle of January, 1953, the receiving station of the South African Broadcasting Corporation at Panorama, near Johannesburg, started to send us reports containing the results of regular hourly observations of the signals of WWV. The observations are made, generally, upon the frequencies 5, 10, 15, 20 and 25 Mc/s, and the reports take the form of the five figures of the SINPO code (1) for each hourly observation. Although the transmission path Washington/Panorama is not of particular interest to the BBC, it was decided to analyse some of the observations in order to extract any useful information from them. The principal aim of the analysis was to obtain information from which a check could be made on the accuracy of the D.S.I.R. world charts of predicted MUF which are supplied monthly to the BBC. These charts are used in the selection of the frequencies for use over numerous BBC short-wave circuits, and any information as to their accuracy would be of use to the D.S.I.R. and the BBC alike. The predicted MUF's upon which the charts are based are obtained by calculation from the measured critical frequency/height data received from a number of observing stations scattered over the earth's surface. This report gives the results of the analysis mentioned above.

3. NATURE OF DATA AND METHOD OF PROCEDURE.

The appropriate D.S.I.R. monthly charts of predicted MUF, when used in conjunction with a great circle map of the transmission path according to the approved method, yield a family of circuit curves of the form of those shown in Fig. 1 which is given only by way of illustration. In this the dashed-line curve shows, against time of day, the predicted MUF for the circuit for the month in question. The full line curve (which is simply a frequency 15% below the MUF) gives a prediction of the so-called Optimum Working Frequency (OWF), which is regarded as the frequency below which communication over the circuit will not be liable to interruption due to the effects of electron limitation in the ionospheric layers on any day of the month except those on which serious ionospheric disturbances occur. Also shown in Fig. 1, though obtained from data other than that supplied by D.S.I.R., is a dot-dash curve which gives the predicted Lowest Useful Frequency (LUF) for the circuit, i.e. the frequency below which communication will be unsatisfactory because of the combined effects of ionospheric absorption and atmospheric noise, having regard to the E.R.P. and the type of communication it is desired to effect. In practice, therefore, it is considered necessary to work between the OWF and LUF, where this is possible.

The horizontal straight lines indicate the frequencies of 5, 10, 15, 20 and 25 Mc/s upon which WWV transmits, and it is seen that, since these, at various times of day, cut through the MUF, OWF and LUF curves, continuous observation of the signal strength on these frequencies should enable one to check whether actual propagation conditions conform to those shown by the prediction curves.

The hourly reception reports sent in from Panorama are in the form of the five figures on the SINPO code, in which the first figure indicates signal strength, the second interference, the third noise, the fourth propagation disturbance and the fifth overall readability. Only the first figure was suitable for use in this analysis as being indicative of propagation conditions alone, for all but one of the others depend on factors other than propagation effects. The first figure indicates signal strength on the basis 0 = nothing heard, 1 = barely audible, 2 = poor strength, 3 = fair strength, 4 = good strength and 5 = excellent strength. These are, of

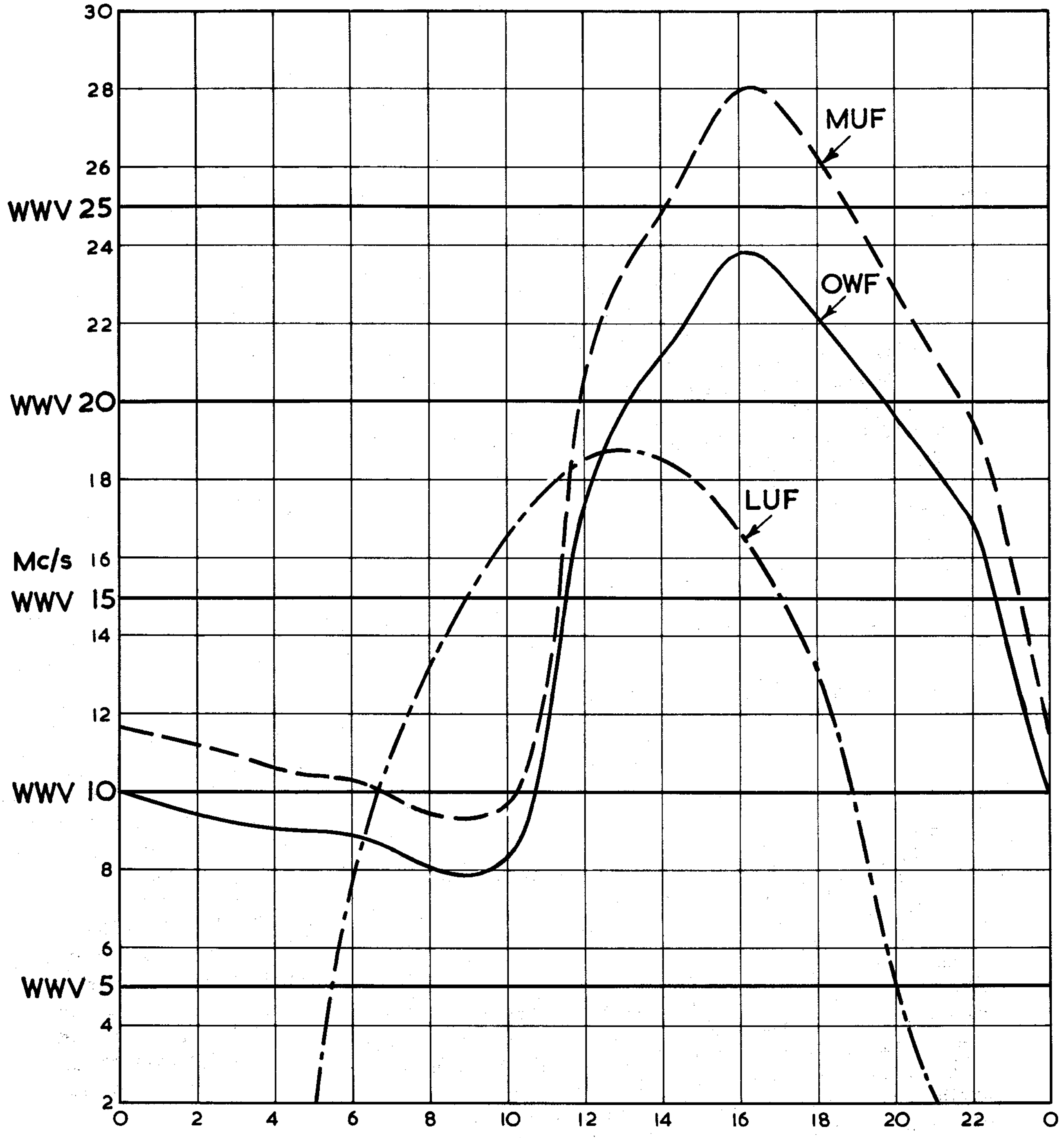


FIG.1
Example of circuit curves for WWV/Panorama path, with WWV transmitting frequencies.

course, subjective measurements and as such their limitations are recognised. Nevertheless, a long series of such measurements made by experienced operators should be of some value.

For each hour of day the mean signal strength was calculated for each month. In the great majority of cases, there were 20 or more measurements per month, but in a few cases there were less. Many of the observations were for zero signal strength and these were, of course, included in arriving at the monthly mean. No notice was taken of those observations which were shown as unreliable due to interference or any other cause. The observations on 10, 15 and 20 Mc/s were generally continuous at hourly intervals throughout the period 0500 - 2030 GMT. On 5 Mc/s the observations were generally useful only for the hours 0500 and 0600 GMT, being afterwards generally spoilt by interference. The observations on 25 Mc/s were only given for a limited number of hours within the period above mentioned. No observations were given for the period 2100 through midnight to 0400 GMT.

The mean monthly signal strength on each frequency having been obtained for each hour, the following symbols were allotted to the various orders of mean signal strength. $\overline{X}$ = 0·1 to 0·9, X = 1·0 to 1·9, ◇ = 2·0 to 2·9, □ = 3·0 to 3·9, O = > 3·9.

The available data was then plotted for each month from February to June, 1953, as in Figs. 2 to 6, as follows. The predicted MUF was obtained for the Washington/Panorama transmission path from the appropriate D.S.I.R. monthly MUF charts, these being the W zone chart for the Washington end of the path and the I zone chart for the Panorama end. This is shown by the upper dashed curve of Figs. 2 to 6, whilst the predicted OWF (obtained from the MUF values) is shown by the lower dashed curve. Owing to the variations in the E.R.P. of WWV on various frequencies, and to several other difficulties, it was decided not to obtain the predicted LUF from the data usually employed (it would not, in any case, be given by the D.S.I.R. charts). Nevertheless, in order to explain the absence or weakness of received signals at certain times of day, the dot-dashed curve is given, and this is obtained from the indications of the signal strength variations themselves, verified by an inspection of the relation of the transmission path to the absorption contours during the different hours of day. The dot-dashed curve may, therefore, be taken as being representative of the "practical" LUF. The symbols indicative of the mean monthly signal strength were then plotted for each hour for each frequency, which is shown by the horizontal line covering the period during which observations were available for each frequency. Where no symbol appears on the horizontal line the meaning is that the signal strength was zero, or, in a very few cases on 10 Mc/s only, the signals received arrived by way of the transmission path running in the opposite azimuthal direction. Finally, the indicated time/frequency areas for satisfactory reception (strengths 3 and 4) were enclosed by the full line contours.

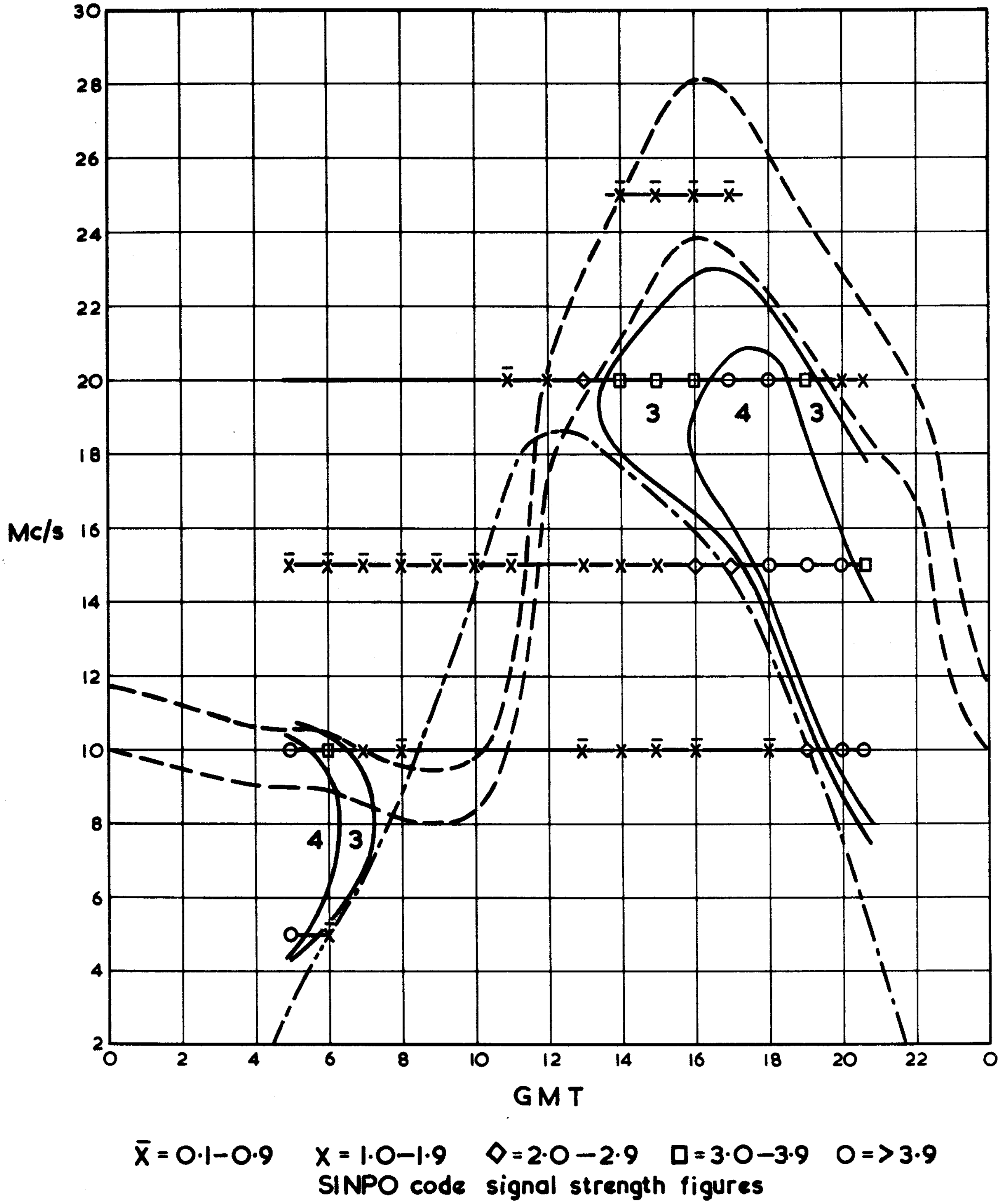
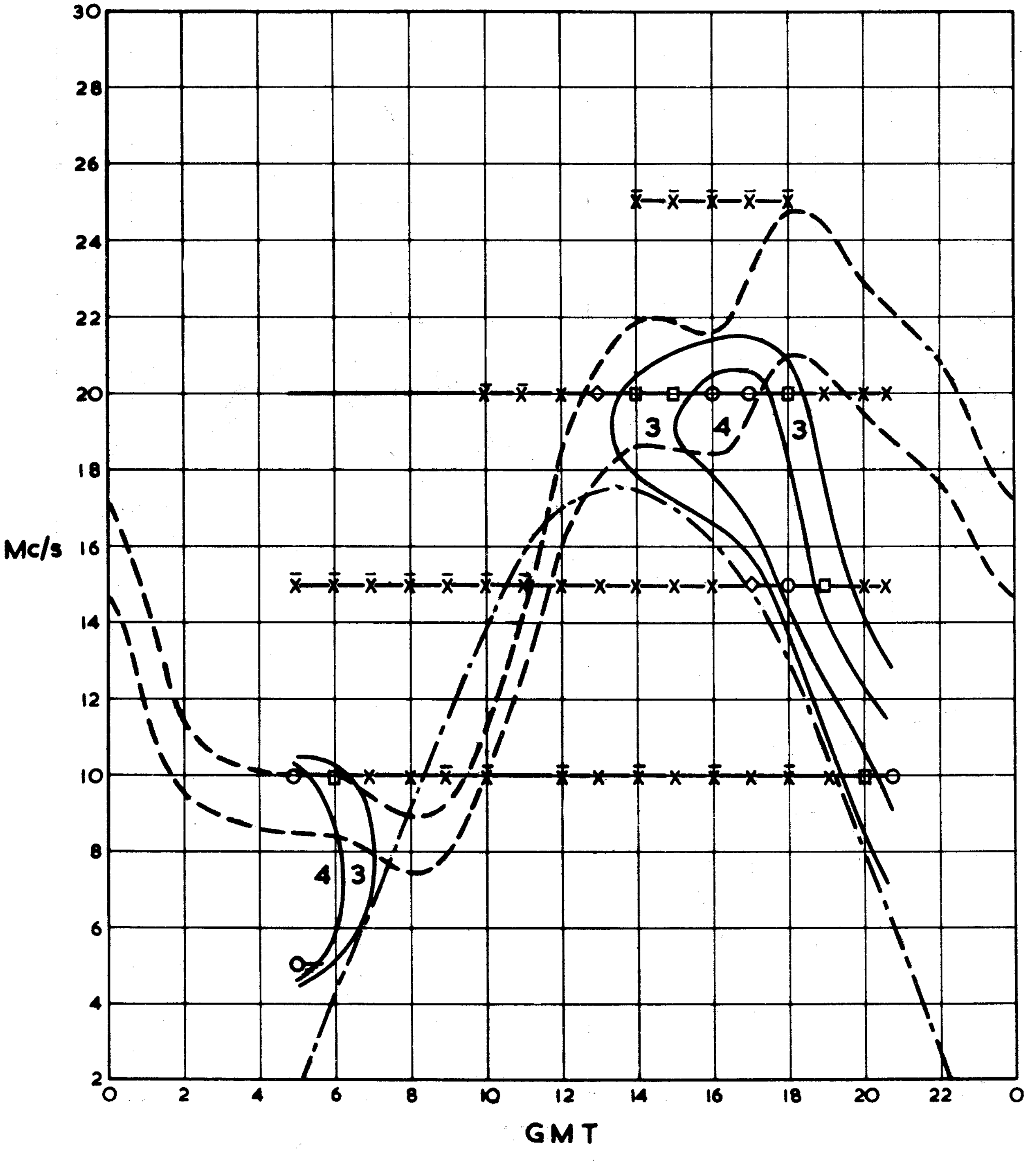


FIG. 2

Reception of WWV at Panorama – February 1953.



$\bar{X}$ = 0·1–0·9 X = 1·0–1·9 ◇ = 2·0 – 2·9 □ = 3·0 – 3·9 ○ = >3·9

SINPO code signal strength figures

FIG.3

Reception of WWV at Panorama – March 1953.

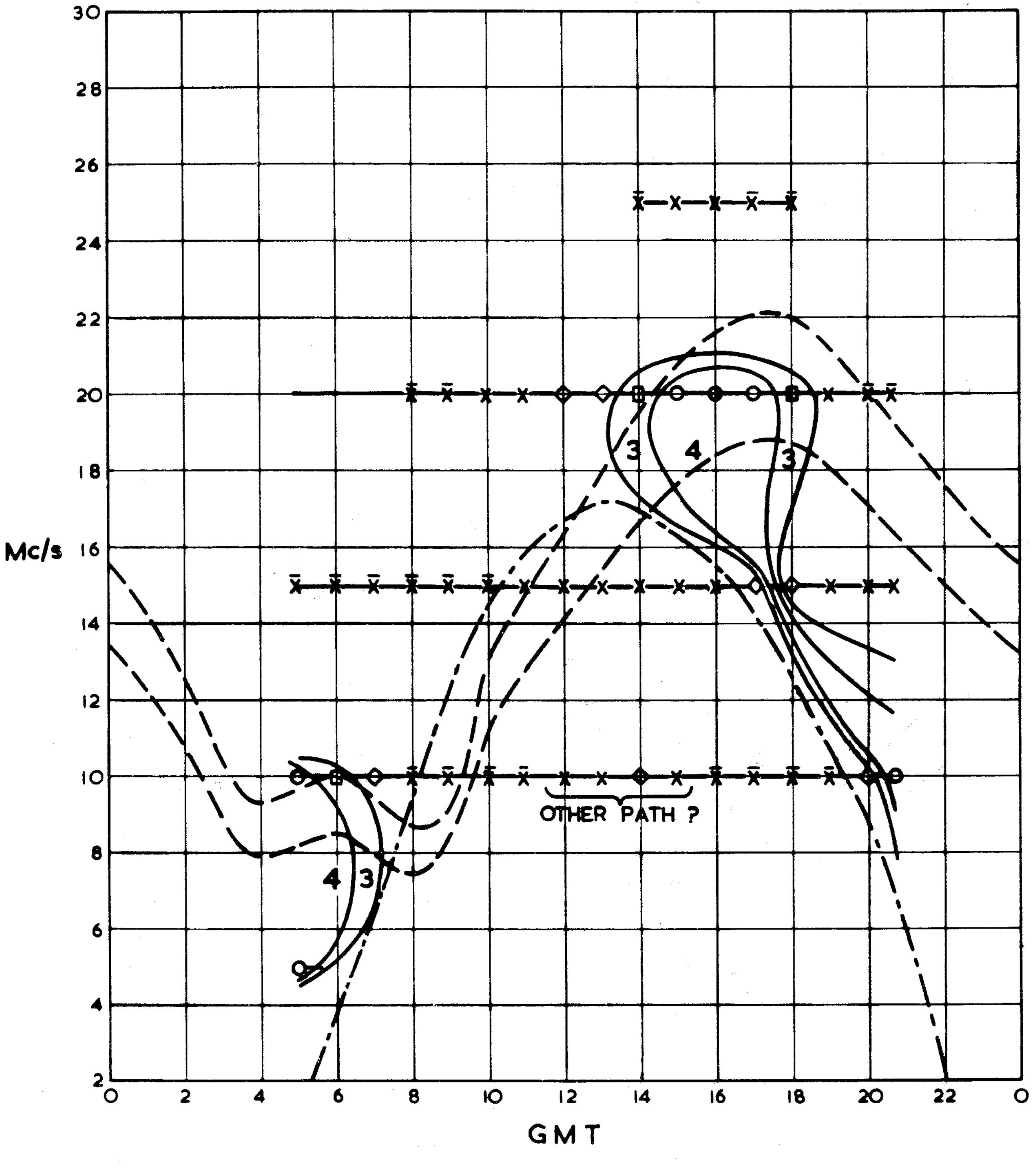
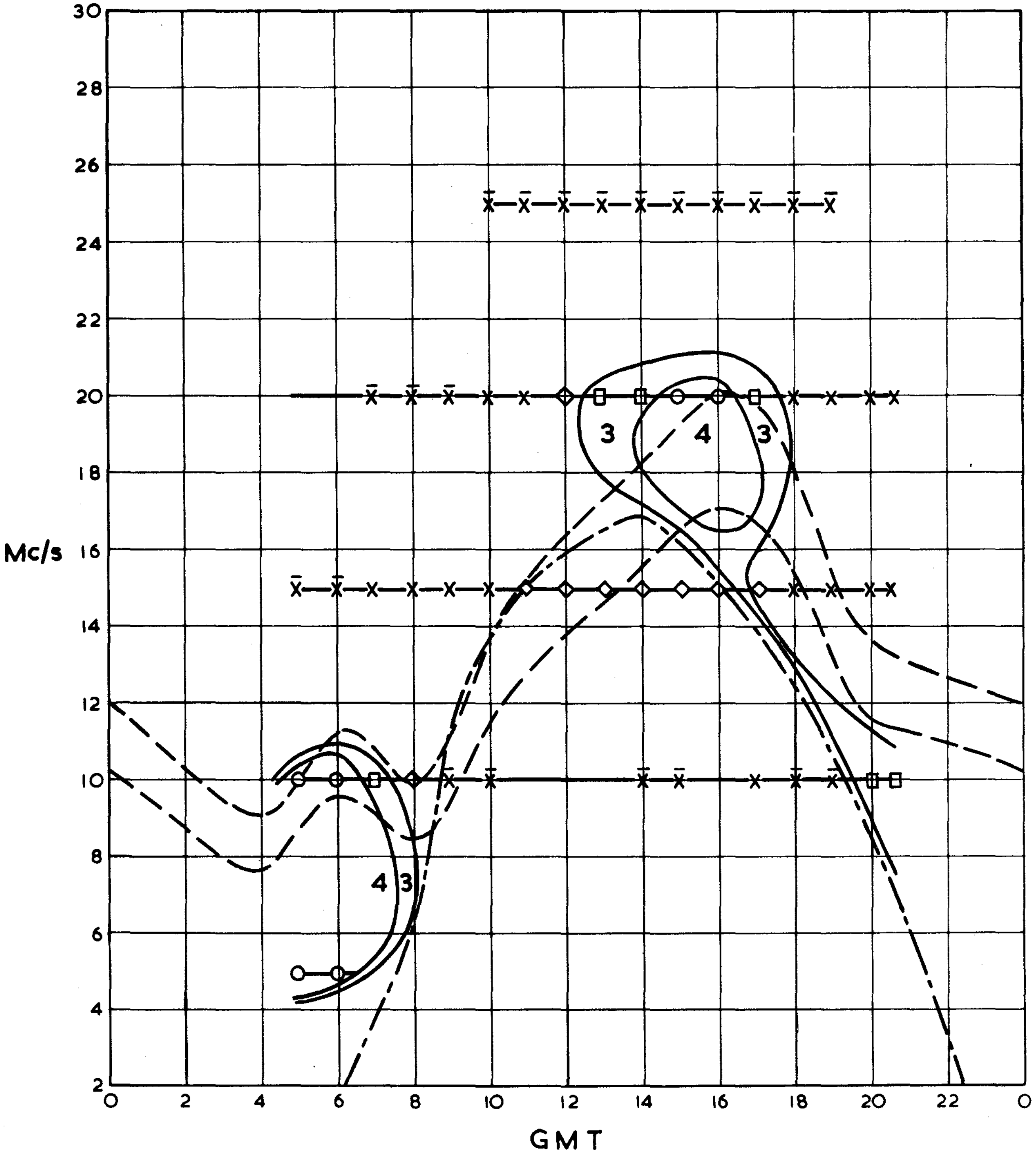


FIG. 4

Reception of WWV at Panorama – April 1953.



$\bar{X}$ = 0·1–0·9 X = 1·0–1·9 ◇ = 2·0 – 2·9 ☐ = 3·0 –3·9 ○ = >3·9

SINPO code signal strength figures

FIG. 5

Reception of WWV at Panorama – May 1953

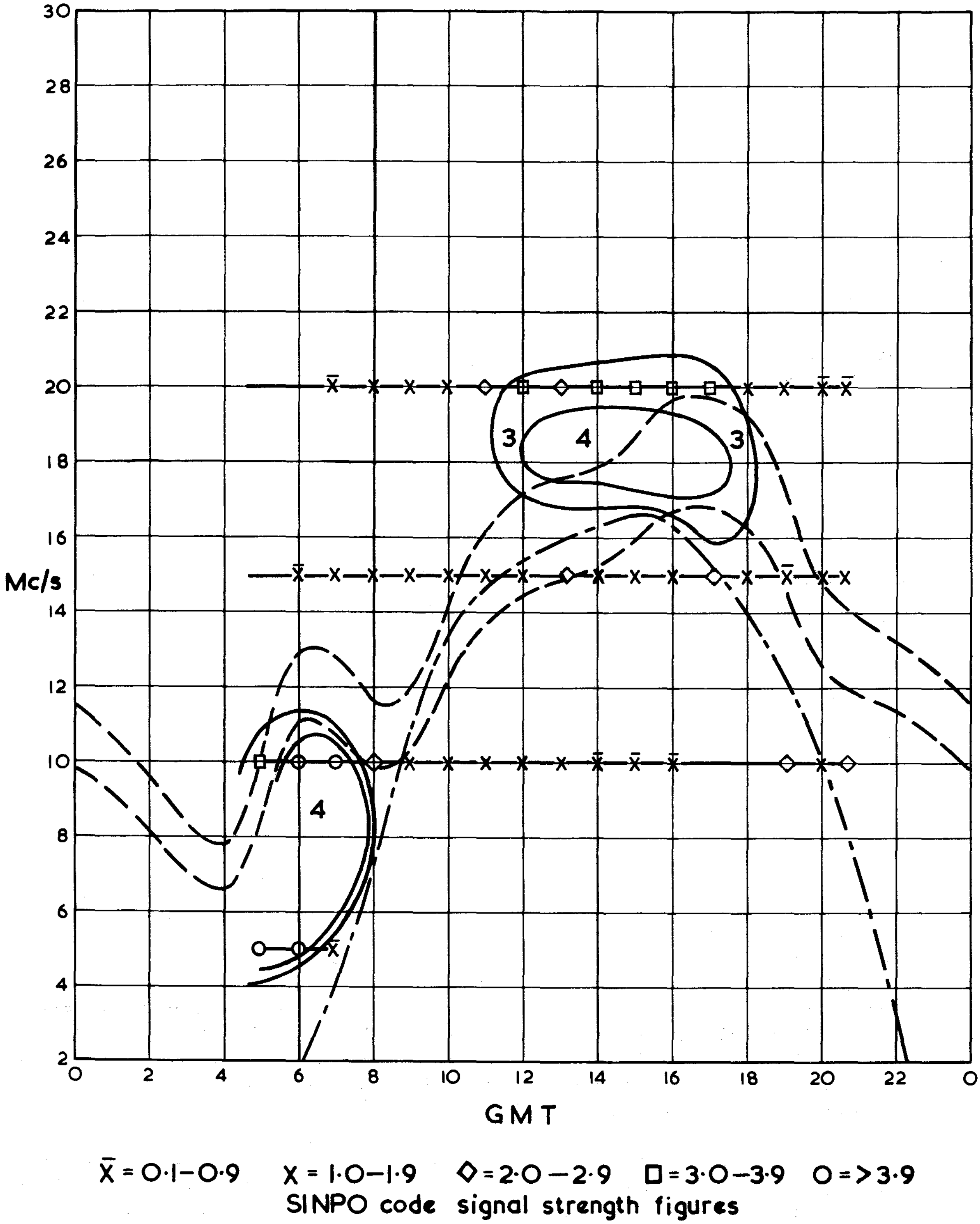


FIG. 6
Reception of WWV at Panorama – June 1953.

4. DISCUSSION OF RESULTS.

4.1 General Features of the Curves.

At 0500 GMT the transmission path is largely in darkness and the MUF is relatively low, whilst the LUF is also very low. Good reception would, therefore, be expected on the lowest frequencies only. From this hour onwards the Panorama end of the circuit is passing into the daylight zone and the LUF increases rapidly. The MUF remains low, however, because of the fact that the control point at the Washington end is still in darkness. By about 0800 GMT so much of the path is in daylight that the LUF rises to a value greater than that of the MUF, and there ensues a period when no good reception would be expected. Round about 1000 GMT, the Washington control point passes into daylight and the MUF begins to increase, but not until 1200 GMT or somewhat later does it reach values higher than those for the LUF, which has all the time been increasing. After this good reception would be expected on the higher frequencies. Some time between about 1200 and 1500 GMT (depending on the month), the transmission path passes through the region of highest absorption and the LUF decreases, to reach extremely low values again by about 2200 GMT when all but the Washington end of the path is in darkness. The MUF begins to decrease from about 1600 GMT, the Washington and later the Panorama control points passing into regions of lower MUF, but, the MUF decreasing at a slower rate than the LUF, good reception would still be expected on the higher, but decreasing, frequencies. This is but a general description of the reasons for the variations shown, but it is seen, from an inspection of the curves, that it will be most convenient to analyse the reception results during three distinct periods, i.e. 0500 - 0800 GMT, 0800 - 1200 GMT and 1200 - 2030 GMT.

4.2 Period 0500 - 0800 GMT.

During this period the Washington end of the circuit controls the MUF during the months of February, March and April, but during May and June (winter in the southern hemisphere) control of the MUF is at the Panorama end till between 0400 and 0600 GMT, when it passes over to the Washington end, this resulting in the double minimum seen in the MUF and OWF curves. The MUF does not vary much with the seasons during this period, however, remaining in the region of 10 Mc/s, except that in May and June it rises above this value. The LUF appears to be very low at 0500 GMT and to rise to values of the order of 10 Mc/s during the period, reaching this value somewhat later in May and June than in the earlier months.

The signal strengths as indicated by the symbols and contours conform, in general, very well to the propagation conditions indicated by the curves during this period, except that the curve for OWF seems to have little meaning. Good signal strength is indicated by the contours as being obtainable from the MUF to frequencies sometimes extending below 5 Mc/s from 0500 to about 0700 GMT during the earlier months, and until somewhat later during May and June. The symbols for 15 Mc/s indicate that the MUF was approximately as indicated by the curve, those for 10 Mc/s that there was a deterioration when this frequency either exceeded the MUF or fell below the LUF, and those for 5 Mc/s that the deterioration on that frequency occurred when it passed below the LUF. It is interesting that in June the signal strength on 10 Mc/s did not reach its maximum until 0600 GMT, this being the only indication during this period that the OWF was of any significance, for good reception was usually obtained not only above, but far below it. Altogether the indications are that, during this period, the MUF curves are substantially correct.

4.3 Period 0800 - 1200 GMT.

During this period the curves indicate that, for the reasons already mentioned, the LUF was generally above or of the same order as the MUF, and that there is no frequency on which good reception should occur. The symbols indicate that signal strength on all frequencies was below that necessary for satisfactory reception, either because they were above the MUF or below the LUF. The results, therefore, conform to the indications given by the curves.

4.4 Period 1200 - 2030 GMT.

This is the period when good reception should have been possible on the higher frequencies.

From 1200 to 1600, the MUF was controlled by the Washington end of the circuit, and it is seen to decrease very considerably from February to June, peak values of predicted MUF varying from 28 Mc/s in February to less than 20 Mc/s in June. This is due to the well-known decrease in daytime F_2 critical frequency in the northern hemisphere from the winter towards mid-summer. From 1600 to 2030, the MUF was controlled variously by either end of the circuit, but, generally speaking, it also shows a general decrease from February to June.

The symbols and the contours for good reception show that the seasonal decrease in the real MUF was, in fact, much less marked than is indicated by the curves, and, furthermore, they indicate that good reception on the higher frequencies was possible over longer periods in May and June than in the earlier months. They also draw attention to some other peculiarities which will be discussed later.

In February, the contours indicate that, from about 1300 to 2030 GMT the high frequency limit for good reception was substantially that indicated by the OWF curve, whilst the low frequency limit was, no doubt, that determined by the LUF. It is to be noted, however, that, when the LUF permitted it, the best class of reception (signal strength 4) extended to frequencies very far below the OWF. In March, the predicted MUF having decreased considerably, good reception was obtainable above the OWF, and in April above the MUF. In May and June this effect is much more pronounced, good reception being obtainable for long periods on frequencies far above the predicted MUF. In fact, whilst the peak predicted MUF decreased from February to June by about 8 Mc/s or 28%, the contours indicate that the peak of the "real" MUF only decreased by about 2 Mc/s or 9%. This, of course, is the same effect which has been noticed before on other circuits i.e. that whilst there is a large seasonal decrease in measured daytime critical frequency in the northern hemisphere, leading to a large decrease in predicted MUF, the highest usable frequencies in practice, whilst showing some decrease, do not, for some reason, decrease to anything like the extent which the predicted MUF indicates.

The contours indicate, between 1600 and 2030 GMT, another peculiar difference between prediction and practice, at least so far as reception at Panorama is concerned. In February the contours follow the OWF during this period, but in March they fall sharply below it from about 1830 GMT, leaving an area on the higher frequency side in which, whilst there seems to be no reason why good reception should not be obtained, none in fact is. The effect is even more marked in April and May, whilst in June it results in the fact that no satisfactory reception is obtained on any frequency between 1800 and 2030 GMT. In May and June this result might be explained by assuming that the LUF is somewhat higher, between 1800 and 2030 GMT, than is shown by the dot-dash curves, but in March and April it remains inexplicable by this assumption. It may well be that this failure of reception on frequencies below the MUF after sunset is due to the equatorial sunset phenomenon reported by Osborne (2), in which there occur very large changes in layer height, followed by the appearance of diffuse scatter. Osborne reports that, as observed at Singapore, the layer at this time disintegrates into a cloud formation, giving a diffuse echo-pattern over a wide range of transmitted frequency, frequently from 2 Mc/s to 13 Mc/s at vertical incidence. There is then no indication of layer formation and rapid and violent fading of the received echo occurs. The disintegration of the layer into clouds was found generally to occur at about the time of sunset on the layer, and to be most prevalent around the equinoxes. Osborne remarks: "It seems unlikely that normal ionospheric reflection can be relied on for transmission through equatorial regions during the period 1900 – 2000 LMT at the equinoxes." Normal layer formation is restored some time later during the night.

A similar effect had previously been observed in Huancayo, which lies in approximate latitude 12° S. The southern control point on the circuit Washington/Panorama lies in approximate latitude 14° S., i.e. in an equatorial region where such effects might be expected. The reception failure on the higher frequencies is seen from the curves to start at about 1830 GMT, corresponding roughly to the time of sunset on the layer, at the control point. Numerous previous reports received from Panorama indicate a similar deterioration of reception after sunset, particularly at the equinoxes, and there therefore seems to be a strong probability that the sharp fall in the contours for good reception shown in the curves is due to this tropical sunset effect, which results in inefficient propagation in the F_2 layer at the southern end of the path.

5. CONCLUSIONS.

Bearing in mind the subjective nature of the data, the following conclusions are drawn:

(a) During the early morning period the predicted MUF curve is substantially correct, and during the period 0800 - 1200 GMT signal strength is low on all frequencies, as would be expected, because they are either below the LUF or above the MUF.

(b) For the period following on 1200 GMT good reception is obtained, as would be expected, on the higher frequencies, but the seasonal decrease in predicted daytime MUF is much greater than that which occurs in practice. The result is that the predicted MUF becomes progressively too low from April onwards and good reception is obtainable on frequencies well above it. These two conclusions together indicate that errors in predicted MUF are serious in summer daytime only.

(c) The so-called OWF is shown to be of little significance, for good reception is obtainable on frequencies, not only considerably above it, but also, when the LUF permits, on those far below it.

(d) In Panorama, for some time after local sunset, there is a range of frequencies below the MUF and above the LUF on which good reception would be expected, but is not, in fact, obtained during equinoctial and summer months. There is a strong probability that this may be due to the tropical sunset effect reported by Osborne, at least so far as equinoctial months are concerned.

(e) Further investigation of this failure in reception after sunset is considered desirable at a number of places, using more objective measuring methods. This is because it is of considerable importance in short-wave broadcasting.

6. ACKNOWLEDGMENTS.

Thanks are due to Mr. R. Morris, E.i.C. of the Panorama Receiving Station of the South African Broadcasting Corporation, for supplying the data upon which this report is based.

7. REFERENCES.

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(2) Osborne, B.W. - "Ionospheric Behaviour in the F_2 Region at Singapore", Journal of Atmospheric and Terrestrial Physics, 1951, Vol. 2, No. 1, pages 66 to 78.